of resistances and batteries. Considering the anode circuit of the first bulb, we see that it contains a resistance R_1 and a high-voltage battery E_1. Let $E_1 = 80$ volts, $R_1 = 30{,}000$ ohms, and the current be 1 milliampere. At present ignore the batteries marked e_1, e_1'; then the fall of potential along R_1 is $30{,}000 \times 10^{-3} = 30$ volts. Such a potential difference applied between the grid and filament of the second triode would put this tube completely out of action. It is therefore necessary to introduce a neutralising battery of about 30 volts at the point marked e_1, or at the point marked e_1'. In the latter case the battery will, in fact, be a portion of the battery E. Suppose this to be done, and imagine an electro-motive force e_g to be applied between the input terminals of the amplifier. Then it can be shown that the consequent increase of current in the anode circuit is

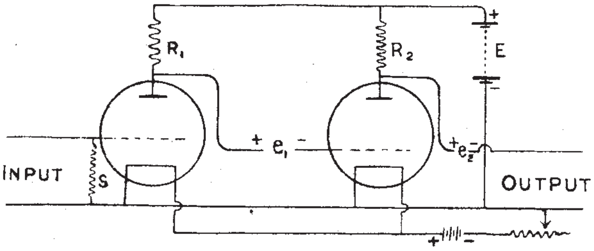

FIG. 2

$$\frac{g e_g}{R_1 + 1/h_a},$$

where g is the triode's voltage factor, and h_a its differential conductance. These parameters are frequently of the order

$$g = 10 \text{ and } h_a = 10^{-4}.$$

The electro-motive force handed on to the second triode from the terminals of R_1 is clearly of magnitude

$$\frac{R_1 g e_g}{R_1 + 1/h_a}.$$

Using the value of R_1 suggested above, we find that the multiplier of e_g becomes

$$\frac{30 \times 10^3 \times 10}{40 \times 10^3} = 7\cdot5.$$

The amplification approaches the limit 10 (that is, the value of g) the greater we take the value of R_1; but obvious practical reasons limit the magnitude of this resistance.

This type of amplifier, usually spoken of as a resistance cascade amplifier, has been much used by the Americans and the French for amplifying rapidly varying currents, but in that case a condenser is substituted for the battery at e_1; a "grid leak" of order a megohm must then be connected between grid and filament in each triode in order to avoid the accumulation of negative electricity on the now insulated grid. The complete instrument is then usually connected so as to utilise a common battery of 4 or 6 volts for all filaments, and a common battery of about 80 volts for all anodes. Adopting common battery connections, a finished two-stage amplifier is seen in Fig. 2. The grid leak S connected between the first grid and its filament might be about a megohm, and is necessary only when the circuits from which the input to the amplifier comes are such as would otherwise leave the grid insulated. According to the computations given above for one stage, the amplification with this two-stage instrument should be

$$7\cdot5 \times 7\cdot5 = 56\text{-fold}.$$

Finally, a mode of connection due to the present writer may be described. It is shown in Fig. 3, arranged to constitute a two-stage amplifier suitable for use with slowly varying currents. The first triode of the pair has resistances Q_1, R_1, S_1, connected so as to constitute with the bulb the four arms of a balanced Wheatstone bridge. The high-voltage battery E_1 is connected across two opposite corners of the bridge. An electrical stimulus applied to the grid causes the balance to be disturbed, and a corresponding potential difference arises between the filament lead and the junction of Q_1 and R_1. This difference of potential is conveyed to the next triode by direct connections. The magnification is the same as that obtained with the arrangement of Fig. 2 when resistances S_1, S_2 are taken of the same value as R_1 in that figure. A grid leak S is used when necessary, for the reason explained before.

In conclusion, it would be well to point out that in deciding upon the resistances and the voltages to be employed in constructing these amplifiers, the characteristics of the triodes should be kept in mind with the view of using them all at such adjustments that the relation between input and output potential differences is linear, and the magnification therefore free from distortion.

W. H. ECCLES.

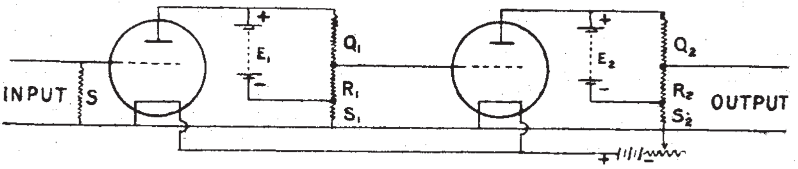

FIG. 3.

INDIAN GEOLOGY.[1]

THE appearance of a manual of Indian geology of so excellent a character as the present work, written by an Indian geologist, is an event of some importance, since it furnishes a fresh and convincing answer to the argument so often put forward that the Oriental mind, though it may assimilate the ideas of Western science with ease, is yet incapable of applying the principles of that science to original research. It is true that the author in his preface modestly admits that the book is in the main a compilation; yet the able manner in which he has marshalled the facts, and the clearness of his reasoning, especially when dealing with matters that are still open to controversy, show that he is by no means lacking in originality of thought and expression.

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[1] "Geology of India for Students. By D. N. Wadia. Pp. xx+398+xx plates. (London: Macmillan and Co. Ltd., 1919. Price 18s. net.

As a text-book for the use of the elementary student, perhaps, the work is not all that is required. There is still room for a book which would lead the student gradually to a knowledge of the science, by illustrations drawn from the rich field of observation that lies open to him in India itself. No systematic attempt is made to explain the meaning of geological terms, and the book presupposes a knowledge of the subject which the average student certainly would not possess. To the advanced student, in the sense that every scientific man is a student throughout his life, the book must prove extremely useful.

There are many pitfalls awaiting the student who fails to profit by the pertinent advice (p. 41) "not to commit the mistake of merely trying to memorise the dry summary of facts regarding the 'rocks' or 'fossils' of a system, or consider that the idea of a geological system is confined to these. These are the dry bones of the science; they must be clothed with flesh and blood by comparing the processes and actions which prevailed when they were formed with those which are taking place before our eyes in the world of to-day. A sand-grain or a pebble of the rocks is not a mere particle of inanimate matter, but is a *word* or *phrase* in the history of the earth, and has much to tell of a long chain of natural operations which were concerned in its formation. Similarly, a fossil shell is not a mere chance relic of an animal that once lived, but a valuable *document* whose preservation is to be reckoned an important event in the history of the earth. . . ." (The whole passage is too long to quote, but it furnishes a good example of the author's style.) In the making of tables of rock-sequence and correlation it is impossible to avoid what appear to be definite statements regarding a formation the position of which may be doubtful; and when the student merely learns these tables by heart for examination purposes (a practice which too often defines the limits of the candidate's knowledge of the subject), he is apt, having missed the qualifying explanation given in the text, to unload his modicum of knowledge with results disastrous to himself. Thus, in the general table of formations (p. 47), the rocks of the Simla area, from the Blaini boulder bed upwards, are boldly correlated with the Vindhyans of the peninsula,

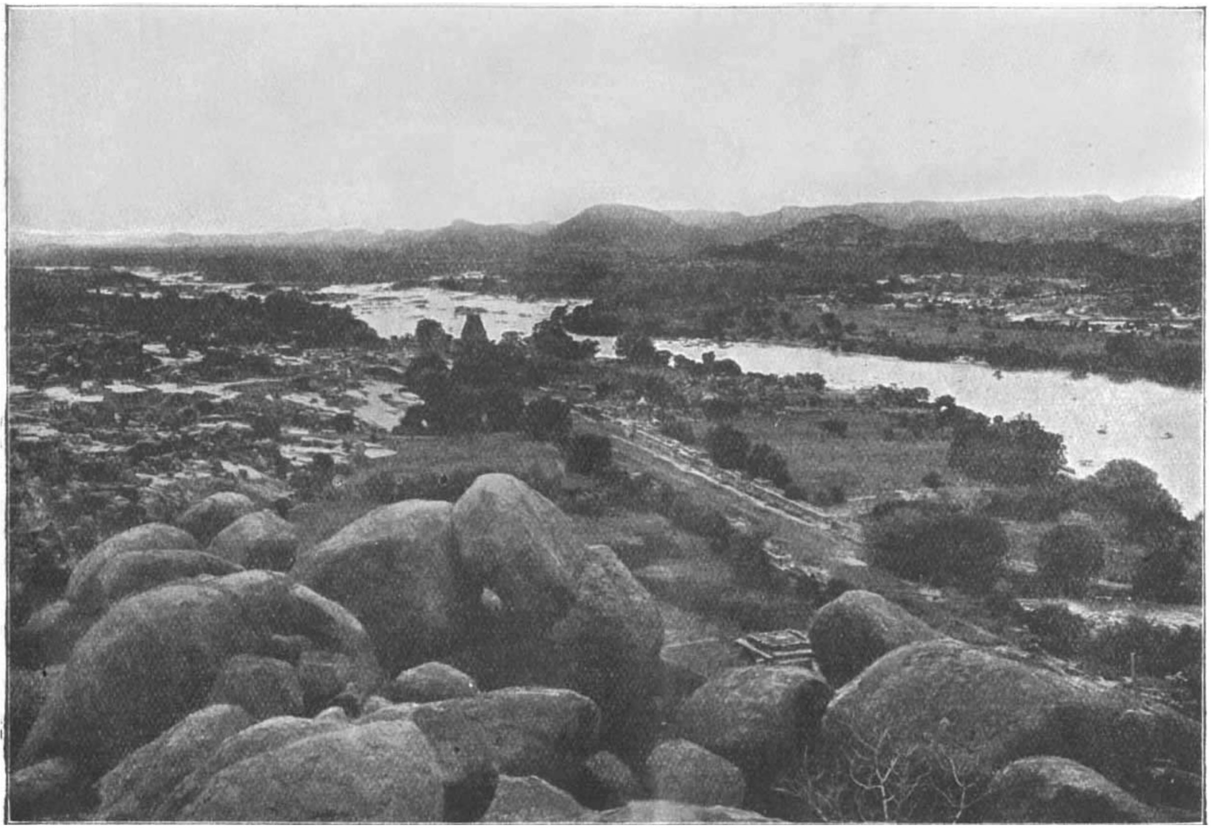

FIG. 1.—Bellary Granite-Gneiss Country, Hampi. From "Geology of India for Students."

though it has not yet been proved that this boulder bed is not the equivalent in age of the Carboniferous Talchers. The Simla and Jaunsar slates, the Dalings of Sikkim, and the Shillong quartzites in Assam are all correlated with the Dharwars of Southern India, and, probable as these correlations may be, even as regards lithological resemblance there is little in common between these formations and the highly altered schists and jaspers of the typical Dharwars. Again, in the table giving the Cambrian succession of the Punjab Salt Range, the salt marl is placed at the base of that system, though it has recently been shown that there is good reason to believe this peculiar formation to be of Tertiary age.

The arrangement of the book follows the usual lines. The physical features, mountains, glaciers, etc., are each briefly dealt with in the opening chapter. (Some of these are again described in a chapter on "Physiography" towards the end of the book (chap. xxv.), a somewhat peculiar arrangement, resulting in a good deal of repetition.) Then follow the various systems from Archæan to Pleistocene and Recent, the information with regard to each being carefully and clearly given in sufficient detail. Full advantage is taken of recent advances in our knowledge of Indian geology. Allusion is made to the revolutionary ideas of Dr. Smeeth and his band of workers in Mysore concerning the age of the Dharwars, which would make them the oldest rocks of the Peninsula (p. 69). Insistence is laid (pp. 135, 150) upon the importance of the stratigraphical break at the close of the Carboniferous period, which separates the Dravidian and Aryan groups of Sir T. Holland's classification of the Indian geological sequence. Full attention is also given to the recent discovery in Kashmir of beds containing the characteristic flora of the Talcher series, associated with marine strata, thus fixing a base limit for the Gondwana system, and closing a long-standing controversy.

A useful chapter on "Economic Geology" closes this part of the work, and then follows a special chapter on the geology of Kashmir, where, as the author remarks, "within a small geographical compass one of the finest developments of the stratified record seen in the Indian region and perhaps in the world" is revealed, in a situation more accessible to the student than any other in the whole length of the Himalaya. It may here be remarked that much remains to be done before the geology of this fascinating country is worked out in detail.

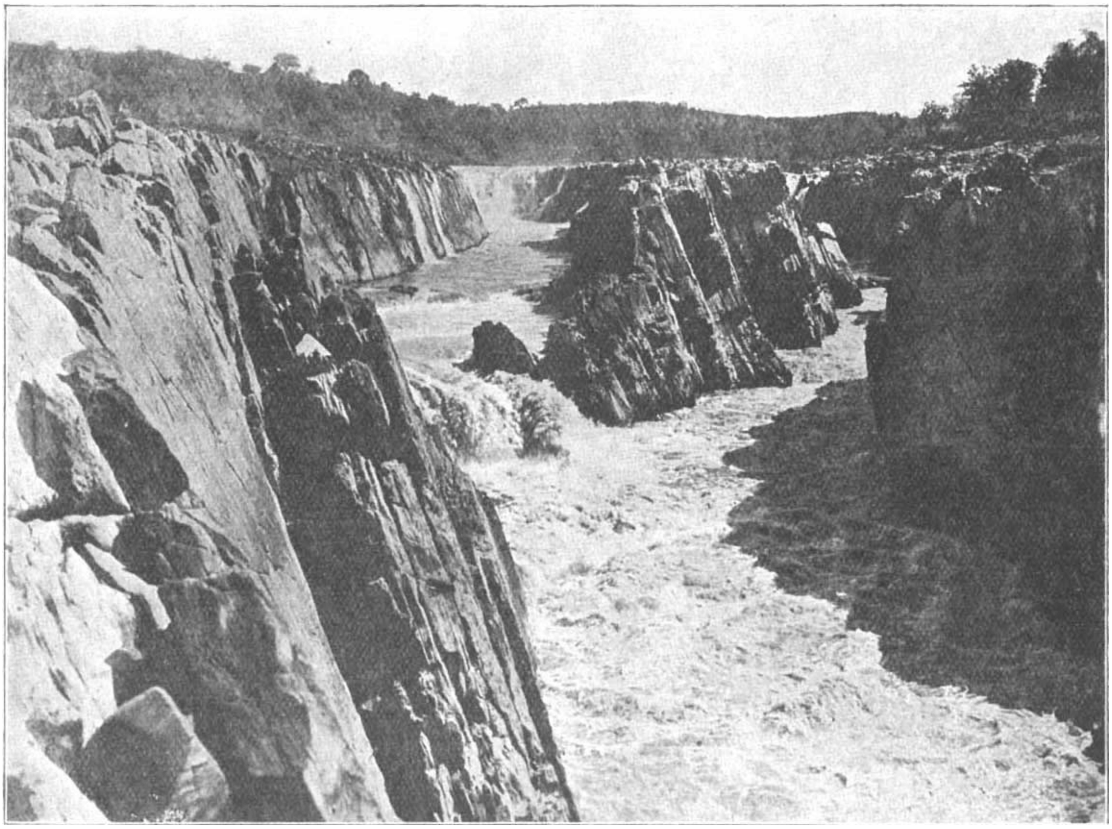

FIG. 2.—"Marble Rocks" (Dolomite marble), Jabalpur. From "Geology of India for Students."

The book is written in clear and good English, and is well got up Very few typographical errors have been noticed, but among them may be mentioned "Jena," presumably for "Jura" of Spiti (p. 165); "corrosion" for "corrasion" (p. 277); and twice (pp. 198, 200) *"Physa princepii"* for the typical fossil of the intertrappean beds of the Deccan, named in honour of the well-known secretary of the Asiatic Society of Bengal, James Prinsep. Numerous photographic views, diagrams, and maps add to the interest of the work, most of which are taken with due acknowledgment from the publications of the Geological Survey of India. Of the author's own views, two have been selected for reproduction, one showing a typical landscape in the crystalline area of the peninsula, and the other that unique feature in one of the great peninsular rivers—the falls on the Narbada, near Jabalpur.

T. H. D. L.

METEOROLOGY IN THREE DIMENSIONS.[1]

IN 1916 Mr. W. H. Dines put together in a concise report the information then available about the pressure, temperature, and density of the atmosphere up to heights of 15–20 kilometres. His report is now published, and should prove extremely useful and informing both to the new generation of meteorologists and to the wider circle whose interest in the atmosphere is non-professional.

The first nine sections deal with the methods and places of observation, the averages and seasonal variations of pressure, temperature, and density, and the stratosphere and troposphere; short accounts of humidity and atmospheric motion are also included.

The tenth and eleventh sections are concerned with the results of the statistical treatment of the original data; the interpretation of these results will provoke much discussion. First, the correlation coefficient between (1) the mean temperature of a vertical column extending from a height of 1 km. to a height of 9 km. and (2) the pressure at the *top* of the column is 0·95. The hydrostatic equation connecting variations of pressure at 1 km. and 9 km. with variations of the mean temperature of the column of air is

$$\frac{\delta p_9}{p_9} = \frac{\delta p_1}{p_1} + \frac{k\delta T}{T^2}.$$

From this it follows that if $\frac{\delta p_1}{p_1}$ is (1) zero or (2) proportional to $\frac{\delta p_9}{p_9}$, then the correlation coefficient between p_9 and T is unity.

The first condition is not fulfilled in temperate latitudes; the second condition would be satisfied if the isobars at 9 km. were parallel to those at 1 km.—*i.e.* if the wind-directions at these levels were identical. But in the troposphere convection is always tending to make the direction of the wind the same at all levels, so that the magnitude of the correlation coefficient found by Mr. Dines may be due to the effectiveness of convection in regulating the wind. It would be interesting to know the differences from parallelism permitted by the 0·05 by which the actual coefficient falls short of unity.

Secondly, if T_0, P_0; T_1, P_1, etc., are the temperatures and pressures at heights of 0, 1, 2, . . 13 kilometres, then the correlation coefficients between corresponding T's and P's, beginning with T_0, P_0, are as follows: ·11, ·42, ·66, ·77, ·84, ·85, ·86, ·86, ·86, ·71, ·32, −·19, −·36, −·28. It follows that pressure and temperature go up and down together with great regularity at all heights between 3 km. and 9 km. Presumably the same would hold for the surface were it not for the effects of radiation and of the surface water of the ocean upon the surface temperature of the air.

Two outstanding deficiencies in the information available call for comment. There are no records from the United States, India, Australia, South Africa, South America, and Japan. This is no doubt partly due to the difficulties of recovering records in these countries if the ordinary European method of investigation is used; but it is also due to the defects of pre-war international meteorological organisation in which no place was found for an active permanent bureau. Further, the information about atmospheric motion is hopelessly inadequate. This arises less from lack of original records than from the absence of any proper arrangements for summarising the results of pilot-balloon ascents. A young meteorologist seeking a field of independent research might do worse than turn to the statistical treatment of vectors.

Before the war the investigation of the free atmosphere was, broadly speaking, pure research; the work had no direct application in forecasting or climatology, and the means of investigation were slight and relatively expensive. During the war a knowledge of the actual conditions of the atmosphere at least up to 20,000 ft. (6 km.) became essential for heavy artillery and for aviation, and their importance for actual daily forecasting began to be dimly recognised. Now that artillery operations are over and aviation is practically restricted to low levels, there is a great risk of the investigation at higher levels by aeroplanes and kite-balloons being neglected; and instead of information being available an hour or two after it was obtained, records would again creep in months or years out of date, with no possibility of immediate practical usefulness.

E. Gold.

SIR THOMAS R. FRASER, F.R.S.

WHEN, in 1877, and then in his thirty-sixth year, Thomas Richard Fraser was called to succeed Sir Robert Christison as professor of materia medica in Edinburgh University, it could scarcely have been anticipated how closely he was to rival his great master in his length of tenure of the chair and in the distinction with which he was to fill it. In his varied spheres of action Fraser attained a commanding position as a physician, as an investigator, and as a professor.

Gifted with acute senses and a fearlessly logical mind, and trained in the habits of accurate observation and experiment in the laboratory, Fraser

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[1] Meteorological Office. Geophysical Memoirs, No. 13. "The Characteristics of the Free Atmosphere." (London: Meteorological Office, 1919.) Price 2s. net.